Enhanced Trial Planning and Problem Resolution Tools to Support Free Flight Operations

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Dr. Daniel Kirk joined the MITRE Corporation in 1988. His work at MITRE has included the development of problem resolution algorithms and requirements for the Automated En Route ATC (AERA) 2 project, and various aspects of the User Request Evaluation Tool (URET) project. He is currently Task Lead for the problem resolution enhancements to URET described in this paper. Dr. Kirk conducted his postgraduate studies at the University of Michigan, and received M.S. degrees in Applied Mathematics (1980) and Electrical Engineering (1986), and a Ph.D. in Psychology (1985).

1 Introduction

This paper reports on research being conducted by The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) into providing enhanced trial planning and problem resolution capabilities to the en route sector controller. The goal of this research is to assist the controller in handling the more complex traffic patterns that can result from a less structured free flight environment, and in maintaining an efficient, strategic mode of ATC operation in heavy traffic situations. This goal is consistent with the Free Flight concept described in [1-3], which includes the provision of enhanced problem resolution support for free flight operations.

These enhanced capabilities are being developed as an extension to the User Request Evaluation Tool (URET) which the FAA is deploying as part of Free Flight Phase 1 (FFP1). URET was derived from CAASD's Automated En Route ATC (AERA) research [4], and is designed to support the sector team strategic planning function. It uses flight plan, track, and wind data as the basis upon which to build trajectories of the projected flight of controlled aircraft and to indicate possible conflicts up to 20 minutes into the future. Further details on URET may be found in [5].

The primary capability currently under development is termed Problem Analysis, Resolution and Ranking (PARR). At controller request, PARR provides a ranked set of resolution maneuvers for aircraft-to-aircraft, aircraft-to-airspace, and/or metering problems. Resolutions are generated in a range of dimensions and directions, and support

is provided for the rapid evaluation and—at controller discretion—implementation of the results. PARR has been recommended as a priority research item by the RTCA Select Committee on Free Flight in its recommendations for Free Flight Phase 2 (FFP2).

An additional capability under development involves the generation of automatically probed sets of altitude, direct-to-downstream fix, and speed maneuvers when the controller initiates the display of the corresponding URET menu. These probe results are used to color code the corresponding menu entries, so that the controller can determine which entries are conflict-free by simply viewing the menu. This enhancement may be used both for resolving existing problems, and for generating conflict-free plans for desired actions where no problem currently exists, e.g., to change an assigned altitude due to turbulence.

Planned steps for the evolution of these capabilities include problem detection and resolution aids for severe weather situations; integration with Traffic Management flow constraints; the use of air/ground data link; and integration into a common en route Sector Team CHI. A Research Management Plan [6] is being prepared by the FAA and MITRE/CAASD to support this incremental development process.

2 Problem Analysis, Resolution and Ranking (PARR)

PARR provides a set of ranked problem resolution advisories to the controller in the form of URET Trial Plans. Current development of PARR is focused on the resolution of aircraft-to-aircraft and aircraft-to-airspace problems as described below and in [7 – 9]. The extension of PARR to develop conflict-free resolutions to metering problems is described in [9].

PARR may be initiated either for an aircraft with one or more indicated problems, or for a specific problem. If initiated for an aircraft, only resolutions that maneuver that aircraft will be generated. If initiated for an aircraft-to-aircraft problem, a set of resolutions for each of the two involved aircraft will be generated (with any given resolution maneuvering only one aircraft).

For a given aircraft to be maneuvered, PARR will search for conflict-free trajectories to resolve all problems with that aircraft (within URET's twenty-minute lookahead horizon) in an ATC-acceptable manner, without introducing new problems. The search process examines each of the following five dimensions/directions, thus yielding up to five resolutions for that aircraft: (a) above the conflict, (b) below the conflict, (c) left of route, (d) right of route, and (e) an increase or decrease in speed.

Each PARR resolution is a complete Trial Plan, i.e., it returns the maneuvered aircraft to its original route, destination, or transition. All maneuvers are within the operational performance envelope of the maneuvered aircraft (typically less than the achievable performance limits of the aircraft), and turn angles are limited to parameter values. All turn angles and speed changes are built and displayed in appropriate magnitude increments (e.g., five-degree increments for turns).

After the set of resolutions has been generated, they are ranked using a numerically weighted combination of factors such as: the start time and criticality of any problems detected in the resolution; the maneuvering status of the aircraft; the sector of control; the Time of Arrival (TOA) impact; and the number of flight levels changed.

The clearance language, which does not assume any particular aircraft equipage, is in terms of heading changes, VORs, VOR radials, altitudes and speeds. The clearance language on the Resolution List is abbreviated as described in Table 1. Preliminary observations by controllers have found the abbreviated clearance language useful in conveying the intent of each resolution in the set in a concise manner, and allowing the controller to quickly find a resolution in the desired dimension and direction.

Standard Form	Abbreviated Form
turn left	←
turn right	→
deg	^{0}
fly present heading	fph
at HHMMZ(ΔMM) . .	[ΔMM. . .]

Table 1. Abbreviated Clearance Language

The abbreviated clearance language of the PARR resolutions are presented on the URET Plans Display, in rank order below the display of the Current Plan(s) on which the resolutions are based. As illustrated in Figure 1, buttons to the left of each entry allow the display of additional information on each plan as desired. Any of the PARR resolution Trial Plans may be displayed graphically, coordinated, or implemented in the same manner as any other URET Trial Plan.

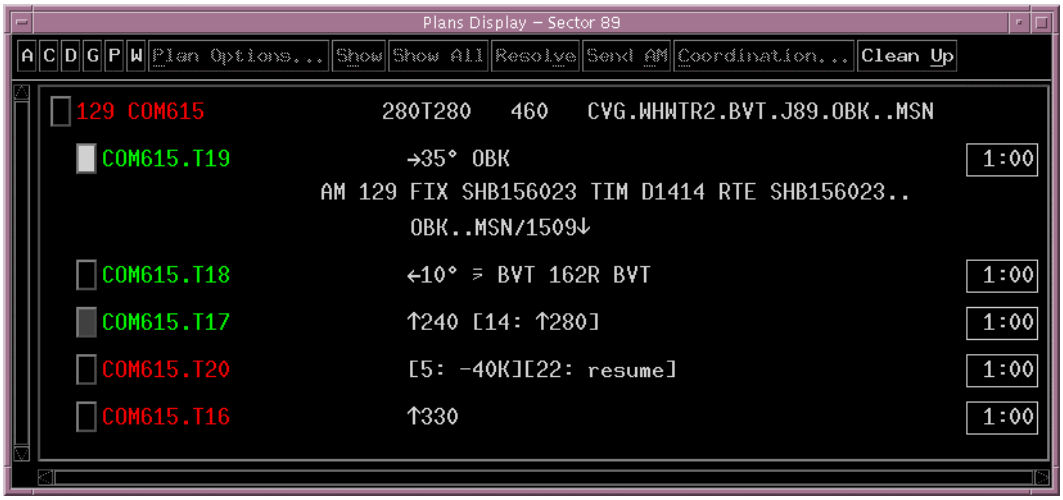

Figure 1. URET Plans Display of PARR Resolutions

2.1 Laboratory Observations

Preliminary laboratory observations with several active controllers familiar with URET include the following:

- PARR reduces workload by reducing the need for additional downstream maneuvers.
- PARR reduces the number of aircraft maneuvers, which is expected to result in fuel, distance, and time savings.
- PARR showed that, when a relatively severe maneuver was necessary, less severe maneuvers did not work.
- As a D-side only tool, PARR was suited for mid- and long-range problems in the en route domain.

3 Conflict-Probed Menu Entries

URET provides menus to facilitate the entry of new assigned altitudes and speeds, and route modifications including direct-to-downstream fix maneuvers. Each menu contains a set of respective altitudes, speeds, and fixes. An enhancement to these menus utilizes a form of AERA Quick Trial Planning (QTP) [4] in which a series of trial plans in a particular dimension are generated on controller request (e.g., a set of trial plans for a range of altitudes above and below the current cruise altitude). The QTP probe results are used to color-code the corresponding menu entries, e.g., a menu entry for a climb to FL330 would be coded red if the Trial Plan to that altitude has at least one conflict that is coded as red. Thus a determination of which alternatives are conflict-free can be made by simply viewing the menu. As with the current URET menus, additional probe details may be viewed in the URET Plans Display after entry selection. Since only the color of the menu entries is affected and no new displays are required, the probed menus are being considered as an initial resolution enhancement.

Probed route and altitude menus have been implemented in a laboratory version of the URET prototype, and preliminary controller evaluation indicates that they are indeed an effective way of conveying probe information on menu alternatives. Similar conclusions regarding probed altitude menus were earlier found in [10].

4 Next Steps

Near-term activities are focusing on continuation of laboratory evaluations with active FAA controllers who have access to URET in daily operational use. A number of operational issues will be addressed during evaluations, including the following:

1. The Concept of Use for each resolution enhancement, and the plan for transitioning to this Concept of Use from current URET operations in a phased, operationally acceptable manner.
2. The overall acceptability of the integrated URET/PARR CHI, clearance representation, and resolution ranking.
3. The ability to generate operationally acceptable resolutions, particularly in complex and/or heavy traffic.
4. Implementation of resolutions with future maneuver actions.

5. Impact on controller workload.
6. Training requirements.
7. Roles and responsibilities of Sector Team members, and coordination with other sectors.

Technical issues that will be addressed include:

1. Algorithmic accuracy of the PARR resolution capability.
2. The definition of metrics and measurement techniques for benefits assessment.

Following completion of the laboratory evaluations, further evaluations will be conducted at FAA field facilities as necessary to fully resolve any remaining operational and technical issues, and to validate the laboratory evaluation conclusions. The plans and schedules for this research are described in [6].

5 Conclusion

Research is being conducted to provide a set of problem resolution advisories to air traffic controllers, to assist in the generation of strategic resolution maneuvers in complex traffic situations. Laboratory analyses to date indicate these capabilities are capable of being implemented as an enhancement to the URET Free Flight Phase 1 system, and can yield significant benefits to both the controller and the airspace user.

6 References

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